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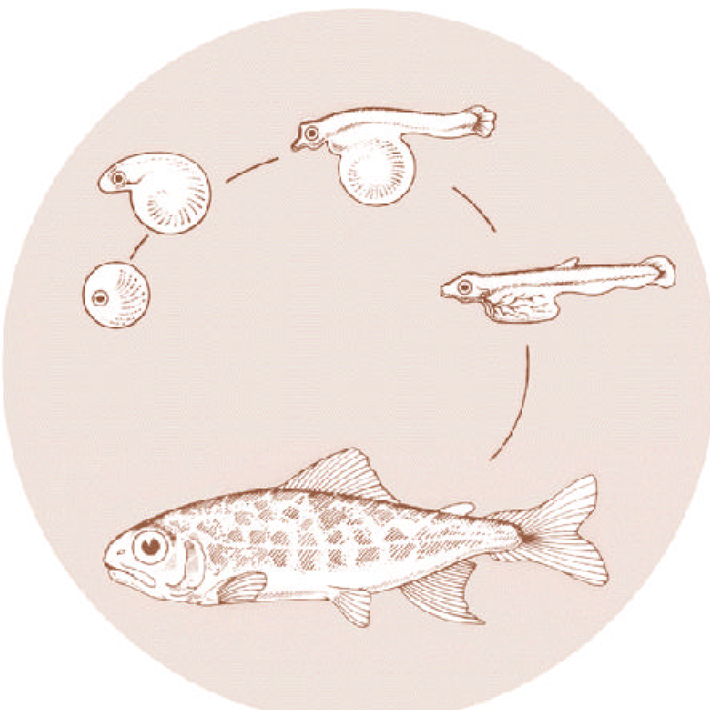
DEVELOPMENT OF RATIONS FOR THE ENHANCED SURVIVAL OF SALMON

Annual Report 1985



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Development of Rations for the Enhanced Survival of Salmon

Annual Report

by

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Abstract

It is believed that hatchery feed nutritional quality plays an important role in determining the health and "fitness" of smoits. Commercial fish meal, the major source of protein in salmon rations, is subject to heat damage during drying and chemical interaction of fat oxidation products with meal proteins. Protein bioavailability is reduced and dietary stress may be introduced into hatchery feeds.

The basic hypothesis of this investigation is that ration protein quality can influence the survival of smoits and the ultimate return of adults. Improved hatchery production would be better able to reestablish natural runs of salmon in the Columbia River and its tributaries and maintain and improve the genetic integrety of specific stocks.

The general approach being used to prove this hypothesis involves a comparison of the hatchery growth response, survival and return of coho and chinook salmon reared on nutrient dense rations containing a very high quality fish protein complement and commercial ration relying on commercial fish meals as a source of protein. Coded wire tagging experiments are being conducted on replicate brood years of test and control fish to determine the influence of ration protein on survival.

Project rearing and release of tagged fish to date include 1982 and 1983-brood replicates of coho salmon and 1983 and 1984-brood replicates of fall chinook (tule stock) salmon. The 1984-brood year replicate of coho salmon is presently being reared and has been tagged for release in April 1986. Planning was completed for rearing a 1985-brood replicate of fall chinook (upriver bright stock) salmon. This report covers the rearing and release of the 1983-brood coho and the 1984-brood fal 1 chinook (tule stock) replicates.

Duplicate lots of coho salmon were reared on two test rations containing vacuum dried salmon and hake meals and a control ration composed of the Sandy hatchery supply of Oregon pellet feed system rations from 1 June 1984 to release on 30 April 1985. A computed 57,981 fish/pond replicate (2.14 g average fish weight) were reared to a 28.75 - 32.67 g average fish weight. of 56,272 to 57,334 fish/pond released, 25,827 - 26,673 possessed a recognizable coded wire tag.

Fall chinook salmon (tule stock) were reared on a test ration containing vacuum dried salmon meal and a control ration composed of the Bonneville Hatchery supply of Oregon feed system rations from 28 December 1984 to 13 May 1985. Fish were initially ponded at 0.61 and 0.64 g/fish in two lots of 504,766 and 564,113 fish/pond: one pond was supplied the test ration and the other the control. The two lots of fish (1.43-1.58 g/fish) were split into duplicate ponds of 215,480 to 260,957 fish each on 31 January 1985 and reared to 5.98 to 7.18 g/fish at release. Of the 150,774 to 213,251 fish/pond released, 78,962 to 60,242 possessed recognizable coded wire tags.

The grouth response of both coho and fall chinook salmon between mid February of 1985 to release in May was altered from that expected by poor test ration palatability. Palatability problems were traced to one of two lots of herring oil used to prepare rations. One lot of oil was not properiy stabilized with antioxidants by the supplier. Although it possessed no chemical characteristics of autoxidation, it did possess a very high potential for oxidation when incorporated into a retion which could not be adequately stabi 1 ized with antioxidants. Ration preparation and oil evaluation protocol have been initiated to guard against a future occurrence.

Introduction

The natural habitat for the spawning and rearing of salmon in the Columbia River system has been reduced by hydroelectric development and other encroachments. Artificial production of salmon in hatcheries has become a critical link in the restoration of natural stocks.

Time of release, natural abundance of food, fish size and the health or “fitness” of smolts play synergistic roles in determining survival and the ultimate return of adult fish. it. is believed that ration nutrition quality plays a major role in determining the effectiveness of hatchery production and the health and/or “fitness” of smolts. Ration regimes containing high quality components in uniform and fine-free pellet forms produce efficient growth response and minimize ioss of nutrients into the hatchery water supply. Quality feeds produce fish less susceptible to disease and of a more uniform and desirabie size at rel ease. High quaiity smolts would help to optimize out-migration and successful adaptation to salt water.

The success of ration in rearing high quality salmon smolts is dependent upon the quality and quantity of their protein compl ement. Although adequate levels of quality energy, essential fatty acids, vitamins and minerals are needed for optimum growth and “fitness” , protein is the major food component in rations. The most successful fish rations rely on large quantities of fish protein in the form of fish meal. Plant sources of protein (soybean and cottonseed meal) are tolerated to a certain extent based upon growth response, but an excessive replacement of fish protein results in a reduction in feed consumption and growth response parameters (conversion and/or weight gain). Their presence in rations represent a dietary stress factor affecting smol t “fitness” .

Commercial fish mea3 supplies needed for formulating successful rations are declining in availabilty and quality. Industrial round (whole) fish that in the past. formed the raw material base for high quality meal production is disappearing because of cost and/or regulation dictating its use for human food. Carcass waste is replacing round fish as a raw material. Resulting meals have a lower protein content. and quality and contain an eievated mineral level because of the removal of muscle tissue for human food. The majority of meals are produced by high-temperature efficient direct flame dryers to meet the specifications of the poultry industry. Variability in raw materials and the need t.o meet protein content requirements for marketability have encouraged excessive heating during drying. Excessive heating damages proteins directly and initiates lipid-protein interactions. Both of these effects reduce the biological value of fish proteins.

The basic hypothesis of this investigation is that ration protein qual ity can aiso influence the survival of smolts and ultimate return of adult salmon to the Columbia River system. It is believed poor quality fish **meals** based upon composition dictated by raw materials or processing damage introduces a dietary stress into fish ration formulations that can affect survival of **smolts** and the ultimate return of adult fish.

Meals and fish protein concentrates produced from round fish and/or upgraded fish processing waste using processes employing low temperature and reduced pressure yields protein of optimum quality. These gentle drying and concentration procedures coupled with the use of fat antioxidants limits heat **damage** to proteins and markedly reduce lipid-protein interactions. Ration regimes incorporating these sources of protein would be more costly, but additional feed costs could be offset by more favorable survival of smolts and return of adult hatchery fish. Hatchery production efficiency would be improved and more hardy **smolts** would **be less** susceptible to disease and mortality.

The general approach being used to prove this hypothesis involves the rearing of coho and chinook salmon on nutrient dense rations containing a high quality fish protein complement. Fish reared of the hatchery supply of commercial ration relying on commercial fish **meals** as a source of protein serve as a control. Coded wire tagging experiments are being conducted on replicate brood years of test and control fish to determine the influence of ration protein on survivai .

Project rearing and release of tagged fish to date include 1982 and 1983-brood replicates of coho salmon and 1983 and 1984-brood replicates of fall chinook (tule stock) salmon. The 1984-brood year replicate of coho saimon are presently being reared and have been tagged. Planning was completed for rearing a 1985-brood replicate of fall chinook (up-river bright stock) salmon. This report covers the rearing and release of the 1983-brood coho and the 1984-brood fall chinook (tule stock) replicates.

Methods and Materials

General Project Operation

This project combines the facilities and expertise of the Oregon Department of Fish and Wildlife and Oregon State University through their Seafoods Laboratory of the Department of Fond Science and Technology. The Oregon Department of Fish and Wildlife carried out required fish husbandry tasks involved in survival feeding trials at their Sandy and Bonneville Hatcheries and conducted coded wire tagging survivai experiments. The task of ration component acquisition and/or production and test ration production and characterization were carried out at the Seafoods Laboratory.

Husbandry Protocol

Coho Salmon, Oregon Department of Fish and Wildlife Sandy Hatchery: Coho salmon (*Oncorhynchus kisutch*) (Sandy stock) were reared in 20x80 x 4 ft. (variable depth) raceways with an actual volume of 4,290 cu. ft. (32,089 gal.) at a maximum water depth of 3.5 ft. Raceways were supplied with 228 to 396 gpm/pond of Cedar creek water at 37 to 66 ^{o}F (three year monthly mean range) (Appendix I). The iowest flow rates occurred during the summer, and the highest during the spring before release of smolts. The hatchery had north and south facing banks of ten ponds each with a separate head box for each bank. The north head box was constructed so that oniy a single pass of water will go into each pond . The south head box was equipped with a pipe and pump system that was used to recirculate water into the headbox (along with the normal creek water). This system was used only during the summer and early fall when the water flow in the creek was too low to meet. the needs of the hatchery. Under normal circumstances, the pump is used only three months during the year.

Swim-up fry were ponded March 26, 1984 at 1,225 fish/lb (0.37 g/fish) and 600,000 fish/pond. Fish were supplied starter ration and progressed through the pellet size guide for salmon recommended by the Oregon Department of Fish and Wildlife for moi st pel I eti zed feeds :

Pellet size (in.)	Fish size	
	fish/lb	g/fish
Starter	1000-700	0.4-0.6
1/32	700-500	0.6-0.9
3/64	500-250	0.9-1.8
1/16	250-150	1.8-3.0
3/32	150-50	3.0-9.1
1/8	50-13	9.1-34.9

Fish (212.36 fish/lb: 2.14 g/fish) were randomiy distributed (in 10 lb lots) into six ponds at a rate of 57,981 fish/pond on April 31, 1984. Control and two test rations were randomly assigned to duplicate ponds/ration; one pond located in the south bank and the other in the north bank of raceways.

Control and two test rations were supplied to fish from June 1, 1984 to release on April 30, 1985. Each ration in recommended pellet sizes was fed by hand to replicate ponds of fish at the feeding frequencies listed as follows:

Fish size (fish/lb)	Feeding frequency (times/day)
1200-800	8-10
800-500	6
500-250	4
250-150	3
150-15	1-2

Control fish were supplied feed according to a feeding guide which schedules fish to be 15 fish/lb (30.2 g) at liberation. Fish supplied test rations were fed at a rate less than the feeding rate guide to achieve equal size at liberation.

Fall Chinook Salmon, Oregon Department of Fish and Wildlife Bonneville Hatchery: Fall chinook (tule stock) (*Oncorhynchus tshawytscha*) were reared in 17.5 x 75 x 3 ft. rectangular circulating type ponds (3,938 cu ft.: 29,456 gal.). Ponds were supplied with well water (49--51 °F) at a rate of 300 to 550 gpm/pond. Water fiow rate was gradually increased from 300 gpm/pond for swim-up fry to 550 gpm/pond and/or to a maximum of 6 lbs of fish/gpm at liberation.

Experimental swim-up fry were ponded into two lots on December 28, 1984 at a rate approximating 600,000 fish/pond at 712-737 fish/lb (.615-.637 g). One pond was suppl ied control ration and the second the test ration until January 31, 1985 when each ration treatment was split into duplicate ponds. Dupl icat e lots of control and test ration fish were thereafter split to meet pro jected pond water flow/fish weight requirements.

Control and test fish were initially supplied starter ration and then progressed through the pellet size guide recommended by the Oregon Department of Fish and Wildlife for moist pelletized feeds 1 isted above. Test ration feeding began with the l/32--inch pellet size. Rations were supplied on a demand basis with Garon automatic feeders.

Pthological Assessment

Oregon Department of Fish and Wildlife pathologists responded to any increase in mortality rates that occurred. At the pathologists discretion, appropriate diagnostic tools were employed to determine the causative agent and remedial treatments were prescribed. Examinations were summarized and reports became a permanent record of the lot of fish involved. During their experimental rearing period coho salmon at Sandy Hatchery were inspected five times, while fall chinook (tule stock) at

Bonneville Hatchery were examined nine times. Both included a preliberation examination.

Growth Response Parameters

Fish weight, feed consumption, feed conversion and mortality information was determined at monthly intervals and reported at two to three month intervals for coho and fall chinook salmon. At liberation, fork length, weight and blood hematocrits were measured and samples of fish from each pond collected for the determination of body composition.

Mean fish weight and length was based on the measurement of three to six randomly selected samples (varying in weight depending on fish size) of the pond populations. Feed consumption and mortality were recorded daily. Feed conversion (feed/gain) was computed wet weight on a cumulative and period basis for interim reporting purposes and on both a wet and dry weight basis for the entire rearing period at liberation. The blood hematocrit level for each pond replicate was the mean of twelve to fourteen fish. Body composition determinations were based upon the mean of duplicate analysis of three randomly selected samples of ten fish/pond replicate.

Coded Wire Tagging Experiments

Coho salmon were injected with a distinctive coded wire tag on 10/4-17/84 at a rate approximating 26,000 fish/pond replicate of control and test fish and marked with an adipose fin clip. Coho were randomly selected for tagging by passing the entire pond of fish over a sampling table which was adjusted to select the desired percentage of fish. Fall chinook salmon were similarly tagged and marked on 4/14-38/85 at a rate approximating 80,000 fish/pond replicate of control and test fish. Fish were randomly selected using a procedure similar to that used for coho salmon. Tag retention numbers from each pond replicate were determined prior to the release of both coho and fall chinook salmon.

Protein Evaluation Design

The hatchery supply of rations composing the Oregon pellet feed system served as a control ration for both coho and fall chinook salmon. This included, when applicable, Biomoist Starter Ration and the OP-4 and OP-2 formulations of the Oregon pellet feed system. Coho salmon were supplied with two test rations deriving their major protein complement from vacuum dried salmon hatchery carcasses and round Pacific hake. A single test ration containing vacuum dried salmon meal as the major protein source was suppiied fall chinook. The major protein complements provided by both vacuum dried salmon and hake were supplemented by hydrolyzed and vacuum concentrated bone-free fish derived from groundfish fillet carcass waste, round Pacific hake or hatchery salmon carcasses.

Ration Component

Advanced Hydrolyzing Systems, Inc. of Astoria, OR, in direct cooperation with the Seafoods Laboratory, produced high quality vacuum dried meal with their equipment using Seafood Laboratory facilities, power and steam. Concentrated Hydeolysates were produced in company facilities. Hatchery carcasses were provided by the Oregon Department of Fish and Wildlife. Hake and groundfish carcass waste were purchased on the open market.

Fish meals were prepared by subjecting coarse ground fish in a steam jacketed chamber equipped with stirring-scraping device to a vacuum equivalent to 25-27 inches of Hg. Product temperature was maintained at 101-105 ^{o}F except for a time period of approximately 5.0 minutes while the product was stili moist when the product temperature was allowed to rise to 180 ^{o}F to achieve pasteurization. Product temperatures upon completion of drying were $\leq$110 ^{o}F. AI1 vacuum dried meals, if not used immediately for ration preparation, were sacked and held frozen $\leq$0 ^{o}F.

Concentrated fish hydrolysates were prepared by exposing coarse ground fish to a temperature approximating 140 ^{o}F with mechanical agitation until sufficent liquefaction was achieved to allow screen removal of bones. The temperature of the liquefied material was raised to 180 ^{o}F to achieve pasteurization and then concentrated in vacuum with scraped surface heat tranfer equipment to approximately 50% solids. Concentrates were sacked or boxed, cooled and then frozen and held at $\leq$0 ^{o}F.

Remaining components required for ration preparation were purchased from commercial firms that either produce moist pelletized fish rations or provide components to the fish feed industry. All purchased components met specifications for the Oregon pellet feed system.

Test Ration Formulation and Production Protocol

Test rations were formulated to contain 28 lb of protein derived from meal and 7.7 lb from concentrated hydrolyzed fish/100 lb of ration. Water and wheat germ meal were balanced to yield rations with 76% solids (24% moisture). Herring oil was added in amounts needed to yield a total ration fat content that provided a ration fat:protein caloric ration of 0.95 (protein = 4.0, fat = 9.0 kcal/g). Computer controlled formulation using the above criteria relied upon the determined compositions of vacuum dried meal and concentrated hydrolyzed fish used for each batch of ration and the general and accepted composition of remaining components. The formulation of test and control rations is listed in Appendix IT.

Ration dry components (vacuum dried fish meal, wheat germ meal, dried whey product, spray dried blood, mineral and vitamin premixes and sodium bentonite) were mixed in 600-1000 lb batches and hammer milled to achieve a fine particle size. Milled dry mix was sacked in 50 lb units and held frozen at 0 to -30 ^{o}F if not immediately used to prepare ration.

Milled dry mix was mechanically mixed with remaining "moist" components (antioxidant stabilized herring oil, choline chloride, concentrated hydrolyzed fish and water) in 150-250 lb batches. The thoroughly mixed components were then mechanically extruded into desired length-diameter pellet forms, screened to remove fines, sacked into 40 lb (l/32-inch pellets only) or 50 lb units and immediately frozen at - 30 ^{o}F.

Ration Composition Control

The proximate analysis (moisture, ash, protein and fat content) of test and control rations was determined to assure composition and for computation of dry weight and protein consumption and conversion. The entire hatchery supply of control ration was sampled by pellet size and if possible, **by** production date. Test rations were sampled during production at a rate of at least two samples from each 150-250 lb mixer batch. The mean for all samples derived from each production day lot which was prepared from the same dry mix formulation was used as the composition of a particular lot of pelletized ration. The composition of control rations was related to feed consumption at the hatchery only by pellet size. The mean composition of each pellet size derived by sampling was used to compute dry weight and protein consumption and conversion. The composition of test rations was directly related to the actual feed consumed.

Analysis of Growth Response Data

Data were analyzed using analysis of variance (one-way classification) procedures. The significance of differences between treatment means was determined using "least significant difference" (LSD) procedures.

Results and Discussion

Introduction

The growth response of both coho and fall chinook salmmon between mid February of 1985 to release in May was compromised by poor test ration palatability resulting in reduced feed consumption and conversion. Initially poor ration acceptance was intermittent, then more uniform in April and May prior to release.

Unfortunately this reduced growth response occurred during a period of high programmed feed consumption for coho and at a time when high feed consumption was desired for fall chinook to reach optimum release size.

Inspection of ration lots having poor Palatability showed the fat fraction of these lots to have attained an unacceptable level of oxidative rancidity. Laboratory storage trials revealed a very rapid development of oxidative rancidity in the frozen pelletized ration. Evaluation of full fat vacuum dried fish meals and frozen concentrated hydrolyzed fish reveal no development of oxidative rancidity . Two lots of fish oil used to prepare rations during this time period, showed no development of oxidative rancidity based upon determined peroxide levels. One lot of oil which was depleted by late March was stabilized according to specifications for the Oregon pellet feed system. A second lot of oil, however, contained only trace amounts of antioxidant. This lot of fish oil obtained from a moist ration producer was supposed to have been stabilized according to Oregon moist pellet feed system specifications by his supplier. Although this lot of oil was not oxidized based upon the presence of determined peroxides, it possessed the potential for developing oxidative rancidity when incorporated into a ration without antioxidant stabilization.

Ration prepared with the same oil with antioxidant added in specified amounts did not yield a stable ration. Although the development of oxidative rancidity and accompanying reduced palatability was retarded, rations became unpalatable in less than two weeks. Stabilization with twice the specified level of antioxidant further retarded the development of oxidative rancidity, but feed became slowly less acceptable with time. Extensive stabilization with antioxidants only slowed the development of oxidative rancidity.

It became apparent that the lot of oil in question possessed an unusual potential for oxidation when incorporated into a ration and the originally determined lack of antioxidant stabilization was not the problem. Even though the oil itself showed no sign of oxidative rancidity it could not be stabilized satisfactorily with antioxidants. Unfortunately, by the time this fact was determined both the coho and fall chinook salmon were near release and no corrective action was feasible. As a result, the 1983-brood of coho and 1984-brood of fall chinook were released under less than ideal conditions.

The characteristics observed for this lot of fish oil were unexpected. Fish oil purchased from this source had been used in the production of Oregon pellets and was used to prepare rations for the 1982-brood coho and 1983-brood of fall chinook salmon without a similar problem.

To guard against a similar problem arising jn the future, the following protocol is being followed with regard to ration stability toward oxidative rancidity: (1) The .02% BHA:BHT (butylated hydroxyanisole:butylated hydroxytolulene) (1:l) specified for the fish oil component is being supplemented with .015% ethoxyquin in the dry portion of the ration. (2) The antioxidant level in purchased oil is being determined using high pressure liquid chromatography; insufficently stabilized oil is being re--stabilized to the level specified for the Oregon moist pellet feed system. (3) Ration production lots are being limited to no more than 2,000 lb/ration treatment. If a similar problem again occurs, ration and oil used will be immediately discarded and replaced with new ration prepared using a second proven lot of fish oil being reserved in frozen storage.

Rearing Results: 1983-Brood Coho Salmon

Duplicate lots of coho salmon were reared on two test rations containing vacuum dried salmon and hake meals and a control ration composed of the Sandy Hatchery supply of Oregon pellet feed system rations from 1 June 1984 to release on 30 April 1985. A computed 57,983 fish/pond replicate (2.14 g average fish weight) were reared to a 28.75 - 32.67 g average fish weight. Of 56,272 to 57,334 fish/pond released, 25,827 - 26,673 possessed a recognizable coded wire tag. The raw growth response data for this rearing period and the numbers of fish reared, released and released with recognizable coded wire tags by replicate pond are [Listed in Appendix TIT.

Coho salmon, from which experimental lots were derived, experienced a cold water disease epizootic prior to the ponding and initiation of test ration feeding on 1 June 1984. Fish were treated with TM-50 and Furox--50. Losses from the disease had declined to acceptable levels by 7 May 1984. Pathological examinations carried out during the remainder of the rearing period (four) revealed only low level symptoms of cold water disease during the winter months which is usual for Sandy Hatchery. Preliberation examination revealed no disease problems.

The quantity of feed consumed by test and control fish varied on a wet (P>.005), dry (P>.005)) and protein (P>.01) basis (Table 1). The lower feed consumption by test fish (P=.O5) was a function of the programmed feed schedule designed to achieve an equal size to control fish at release. Suppiying about 20% less feed to test f'ish in previous feeding trials produced equal sized fish at release. Test rations containing hake and salmon meal as major sources of' protein were consumed in equal (P= .05) amounts.

Table 1. Feed consumption and conversion. 1983-Brood coho salmon; Sandy Hatchery.

Ration	Pond No.	Feed consumption (kg) Wet wt.	Dry wt.	Protein	Feed/gain Wet wt	Dry wt.	Feed protein/ protein gain
Salmon	3	1986.1	1493.8	824.2	1.285	.975	3.136
	14	1994.4	1513.5	835.2	1.280	.971	3.172
Hake	4	2010.8	1518.6	812.0	1.332	1.006	3.144
	13	2037.5	1538.6	822.9	1.331	1.005	3.199
OMP	6	2491.6	1778.8	915.3	1.506	1.075	3.305
	15	2508.4	1790.8	921.5	1.434	1.024	3.057
Salmon	Mean	1990.3[a]	1503.6[a]	829.7[a]	1.283[a]	.973	3.154
Hake	Mean	2024.2[a]	1528.6[a]	817.5[a]	1.331[a]	1.005	3.172
OMP	Mean	2500.0[b]	1784.8[b]	918.4[b]	1.470[b]	1.050	3.181

Significant relationships: feed (wet wt.), $P \geq .005$; feed (dry wt.), $P \geq .005$; feed protein, $P \geq .01$; feed/gain (wet wt.), $P \geq .05$.

Mean values for rations in a column with different exponent letters varied significantly (P=.05).

Table 2. Ration composition. 1983-Brood coho salmon; Sandy Hatchery

Ration		Composition (% wet wt.) Moisture	Ash	Fat	Protein
Salmon	Mean	24.28	7.40	18.56	41.83
n = 12	S.D.	.952	.983	.883	.710
Hake	Mean	24.40	8.93	18.16	40.43
n = 11	S.D.	1.699	.637	1.122	1.410
OMP	Mean	28.65	7.87	12.18	36.55
n =15	S.D.	.993	.265	1.053	1.656

n = number of lots of experimental ration; number of samples of hatchery feed supply taken through rearing period for OMP.

Conversion of test and control rations varied ($P \geq .05$) only on a wet weight basis; feed (dry wt.) and feed protein/protein gain were equal ($P \leq .05$). Test rations were converted slightly more efficiently (P=.05) on a wet weight basis than control rations

(Table 1), but this superior conversion was largely a function of the lower moisture content of test rations (Table 2). Feed (wet wt.)/gain for test rations containing vacuum dried salmon and hake meal as major protein complements were equal (P=.05).

The gain produced by fish during the rearing period supplied test and control rations varied significantly and resulted in the release of fish varying in size (P≥.05) (Table 3). Control fish gained significantly more weight during the rearing period and were released at larger size (P=.05). Fish supplied the test ration containing vacuum dried salmon meal gained slightly more than fish receiving vacuum dried hake meal, but gain and fish release size did not vary significantly (P=.05).

Fish supplied control and test rations did not vary (P≤.05) in length, condition factor, blood hematocrit, mortality (Table 3) or in body composition (Table 4) upon release. The condition factor for control fish was slightly better than the factor computed for test fish, but their mean blood hematocrit level was somewhat less.

Table 3. Fish release size, gain, length, condition factor, hematocrit and mortality. 1983-Brood coho; Sandy Hatchery.

Ration	Pond No.	Fish Release wt. (g)	Weight gain (g/fish)	Length (mm)	Condition factor[1]	Hematocrit (%)	Mortality (%)
Salmon	3	29.41	27.28	140.9	1.051	34.7	2.9
	14	29.34	27.20	140.8	1.051	38.9	1.1
Hake	4	28.75	26.62	140.1	1.046	34.3	2.0
	13	28.93	26.79	139.3	1.071	34.3	1.3
OMP	6	31.44	29.30	141.8	1.104	31.9	2.4
	15	32.67	30.53	141.6	1.152	35.6	1.1
Salmon	Mean	29.38[a]	27.24[a]	140.9	1.051	36.8	2.0
Hake	Mean	28.84[a]	26.70[a]	139.7	1.059	34.3	1.7
OMP	Mean	32.05[b]	29.92[b]	141.7	1.128	33.8	1.8

[1] [100000 x wt. (g)]/[length (mm)^3].

Significant relationships: fish release wt. (g), P≥.05; weight gain (g/fish), P≥.05.

Mean values for rations in a column with different exponent letters varied significantly (P=.05).

Table 4. Body composition. 1983-Brood coho; Sandy Hatchery.

Pond No. /Ration	Composition (% wet wt.)				Composition (% dry wt.)		
	Moisture	Ash	Fat	Protein	Ash	Fat	Protein
3/ Salmon	73.30	2.39	8.16	17.16	8.95	30.54	64.27
	.248	.041	.218	.235	.075	.676	1.010
14/ Salmon	73.53	2.34	8.01	16.90	8.85	30.25	63.84
	.321	.024	.386	.056	.154	1.101	.966
4/ Hake	73.41	2.39	7.93	17.11	8.99	29.81	64.35
	.338	.029	.291	.073	.197	.728	.541
13/ Hake	73.53	2.40	7.94	16.80	9.06	30.02	63.47
	.321	.005	.531	.033	.093	2.377	.869
6/ OMP	73.99	2.27	8.05	16.74	8.73	30.93	64.35
	.262	.037	.413	.070	.157	1.295	.376
15/ OMP	73.24	2.34	7.93	17.24	8.84	29.65	64.43
	.085	.039	.050	.131	.131	.213	.297
Salmon Mean/S.D.	73.24	2.38	8.27	16.99	8.88	30.92	63.50
	.284	.032	.302	.145	.114	.889	.988
Hake Mean/S.D.	73.47	2.39	7.94	16.95	9.02	29.92	63.91
	.329	.017	.411	.053	.145	1.552	.705
OMP Mean/S.D.	73.62	2.30	7.99	16.99	8.79	30.29	64.39
	.173	.038	.231	.101	.144	.754	.337

n = 3 replicate samples/pond.

Mean values for rations in columns did not vary significantly (P=.05).

Reduced weight gain and smaller release size of test over control fish was the major growth response result from the rearing of the 1983-brood coho. Programmed feeding at 20% less than control fish was not compensated for by expected and previously observed better conversion by test rations. Additional test feed supplied fish in the latter part of their rearing period to achieve the desired release sizes was not consumed because of poor palatability and resulted in reduced conversion.

Rearing Results: 1984-Brood Fall Chinook

Fall chinook salmon (tule stock) were reared on a test ration containing vacuum dried salmon meal and a control ration composed of the Bonneville Hatchery supply of Oregon feed system rations from 28 December 1984 to 13 May 1985. Fish were initially ponded at 0.61 and 0.64 fish/g in two lots of 504,766 and 564,113 fish/pond; one pond was supplied the test ration and the other the control. The two lots of fish (1.43-1.58 g/fish) were split into duplicated ponds on 31 January 1985 of 215,480 to 260,957 fish each. Duplicate ponds of fish were then reared to a release at 5.98 to 7.18 g/fish. Of the 150,774 to 213,251 fish/pond released, 78,962 to 80,242 possessed recognizable coded wire tags. The raw growth response data for the rearing period and the numbers of fish reared, released and released with recognizable coded wire tags by replicate pond are listed in Appendix IV.

Pathological evaluations initiated because of increased fish loss during the rearing period identified only minor signs of disease. Tail and fin fungus/rot was identified on 3 January 1985; cultures indicated an external myxobacteria infection. Losses declined without recommended treatment. Fish were given two treatments of potassium permanganate (two-one hour constant flush treatments; 1.0 ppm first treatment, 1.5 ppm second treatment) for bacterial gill disease during 4 to 6 March 1985. By 14 March 1985, fish showed no symptoms of bacterial gill disease and no adverse effects of potassium permanganate treatment. No symptoms of disease were observed on 3 April and prior to liberation on 17 April 1985.

Test and control rations (Table 5) supplied fall chinook salmon were consumed in significantly different amounts during the rearing period (wet wt., $P \geq .01$; dry wt., $P \geq .01$; protein, $P \geq .025$) (Table 6). The conversion of test ration on a wet and dry weight basis was reduced from that of the control ration, but not significantly ($P \leq .05$) (Table 6). Protein conversion (feed protein/protein gain) was inferior ($P \geq .05$) to the control ration.

Table 5. Ration composition. 1984-Brood fall chinook; Bonneville Hatchery.

Ration		Composition (% wet wt.)			
		Moisture	Ash	Fat	Protein
Salmon	Mean	23.95	7.38	17.79	42.10
n = 12	S.D.	.63	.18	1.01	.78
OMP	Mean	26.51	8.58	14.42	38.30
n =15	S.D.	1.45	1.52	1.03	2.24

n = number of lots of experimental ration; number of samples of hatchery feed supply taken through rearing period for OMP.

Table 6. Feed consumption and conversion. 1984-Brood fall chinook; Bonneville Hatchery.

Ration	Pond No.	Feed consumption (kg) Wet wt.	Dry wt.	Protein	Feed/gain Wet wt.	Dry wt.	Feed protein/ protein gain
OMP	D-8	1985.1	1463.3	759.0	1.25	.92	3.09
	D-9	2073.6	1527.7	792.7	1.27	.94	3.13
Salmon	D-4	1545.1	1172.1	648.1	1.28	.97	3.58
	D-5	1525.7	1157.3	640.6	1.31	1.00	3.67
OMP	Mean	2029.4[a]	1495.5[a]	775.9[a]	1.26	.93	3.11[a]
Salmon	Mean	1535.5[b]	1164.7[b]	644.3[b]	1.30	.98	3.63[b]

Significant relationships: feed (wet wt.), $P \geq .01$; feed (dry wt.), $P \geq .01$; feed protein, $P \geq .025$; feed protein/ protein gain, $P \geq .05$.

Mean values for rations in a column with different exponent letters varied significantly (P=.05).

Fish supplied test ration gained less ($P \geq .025$) weight during the rearing period and were released at a lighter ($P \geq .025$) weight and shorter ($P \geq .05$) length than fish supplied the control ration (Table 7). The condition factor, blood hematocrit level and mortality rate (%/day) of control and test fish were statistically equal ($P \leq .05$) at release. The condition factor and blood hematocrit levels observed for control fish, however, were somewhat better than determined for test fish at release.

Table 7. Fish size, gain, length, condition factor, hematocrit, mortality. 1984-Brood fall chinook; Bonneville Hatchery.

Ration	Pond No.	Fish release wt. (g)	Weight gain (g/fish)	Length (mm)	Condition factor[1]	Hematocrit (%)	Mortality (%/day)
OMP	8	7.39	6.78	87.8	1.091	33.8	.016
	9	7.81	7.19	89.3	1.096	34.6	.021
Salmon	4	6.19	5.56	83.3	1.073	33.1	.017
	5	5.98	5.34	82.0	1.082	30.1	.014
OMP	Mean	7.60[a]	6.98[a]	88.6[a]	1.094	34.2	.019
Salmon	Mean	6.09[b]	5.45[b]	82.7[b]	1.078	31.6	.015

[1] $[100000 \times \text{wt. (g)}]/[\text{length (mm)}^3]$.

Significant relationships: fish release wt. (g), $P \geq .025$; weight gain/fish (g), $P \geq .025$; length (mm), $P \geq .05$.

Mean values for rations in a column with different exponent letters varied significantly (P=.05).

The body composition (wet wt.) of fish supplied test ration varied from that of control fish in moisture ($P \geq .01$), fat ($P \geq .05$) and protein ($P \geq .01$) content (Table 8). Test fish were higher in moisture content and lower in fat and protein content at release. Differences in composition wet weight were largely a function of a higher moisture content in test fish. The protein content of test fish dry weight was significantly ($P \geq .005$) higher than control fish. Ash and fat content dry weight were equal ($P \leq .05$).

Table 8. Body composition. 1984-Brood fall chinook; Bonneville Hatchery.

Pond No. /Ration	Composition (% wet wt)				Composition (% dry wt.)		
	Moisture	Ash	Fat	Protein	Ash	Fat	Protein
4/ Salmon	78.03	2.11	5.36	15.00	9.62	24.41	68.27
	.192	.012	.319	.110	.141	1.253	.103
5/ Salmon	78.01	2.15	5.31	15.02	9.78	24.15	68.31
	.235	.033	.155	.197	.197	.476	.396
8/ OMP	77.33	2.13	5.69	15.42	9.41	25.10	67.99
	.164	.042	.065	.158	.128	.148	.471
9/ OMP	77.20	2.13	5.59	15.50	9.33	24.48	67.99
	.323	.012	.475	.028	.148	1.728	.990
Salmon Mean/S.D.	78.02^a	2.13	5.34^a	15.01^a	9.70	24.28	68.29^a
	.213	.022	.237	.153	.169	.865	.250
OMP Mean/S.D.	77.26^b	2.13	5.64^b	15.46^b	9.37	24.79	67.99^b
	.243	.027	.270	.093	.137	.938	.730

n = 3 replicate samples/pond.

Significant relationships: body moisture (%), $P \geq .01$; body fat (% wet wt.), $P \geq .05$; body protein (% wet wt.), $P \geq .01$; body protein (% dry wt.), $P \geq .005$.

Mean values for rations in a column with different exponent letters varied significantly ($P = .05$).

Poor test ration palatability restricted the consumption of supplied feed resulting in inferior conversion and weight gain to that observed for control rations. Fall chinook were released at a smaller size and with a higher body moisture content which may be indicative of less mature fish. Although poor ration palatability did not result in an elevated mortality or a significantly reduced condition factor over control fish, lower blood hematocrit levels indicated that the oxidative state of the fat fraction of test rations probably did affect the physiological condition of fish.

APPENDIX I. Water Temperatures (^{O}F); Sandy Hatchery

	1983			1984			1985		
Month	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
January	44	42.5	43.3	42	40	41	39	37	38
February	45	44	44.5	45	42.5	44	39	37	38
March	47	45	46	47	44	45.5	43	40	41.5
April	49.5	45	47	47.5	44	45.8	48	44	46
May	54.5	49.8	52.1	51	47	49	52	47	49.5
June	56	52	54	54	50	52	56	51	53.5
July	56.6	53.4	55	61	54	57.5	66	58	62
August	61	56	58.5	62	56	59	61.4	55.2	58.3
September	60	45	54	60	48	54	59	48	53.2
October	51	47	49	49	47	48	48.7	46.1	47.4
November	47	46	46.5	45	44	44.5	41.2	39.7	40.5
December	41	39	40	41	40	40.5	36.7	35.9	36.3

APPENDIX II Ration Formulation

Component	Control ration	Test Rations: Hake meal	Test Rations: Salmon meal
Fish meal	28.0 (min)[1]	40.0-48.4[14]	37.7-40.0[14]
Cottonseed meal	15.0[2]	0.0	0.0
Dried whey product[3]	5.0	2.0	2.0
Wheat germ meal[4]	Remainder	Remainder	Remainder
Corn distillers solubles[5]	4.0	0.0	0.0
Trace mineral premix[6]	0.1	0.1	0.1
Vitamin premix[7]	1.5	1.5	1.5
Spray dried blood meal[8]	0.0	2.0	2.0
Sodium bentonite	0.0	2.0	2.0
Concentrated hydrolyzed fish[9]	0.0	22.3	22.3
Choline chloride[10]	0.5	0.5	0.5
Pasteurized wet fish[11]	30.0	0.0	0.0
Fish oil	6.0-6.75[12]	1.8-8.0[13]	7.7-8.4[13]
Water	0.0	7.4-12.4	8.1-10.5
Total	100.0	100.0	100.0

[1]Herring meal (min. 67.5% protein) used at no less than 50% of the fish meal in each batch. Anchovy (min. 65% protein), capelin (min. 67% protein), or hake (min. 67% protein) meals may be used as the remainder. Level to supply not less than 21.5% fish meal protein; max. 5% NaCl; 8-12% fat; max 17% ash.

[2]Preprocessed, solvent extracted, min. 48% protein, max 0.055% free gossypol.

[3]Min. 12% protein, max. 6% moisture, max. 10% ash, max. 3% salt

[4]Min. 23% protein and 7% fat

[5]May contain up to 30% "grains" in place of solubles

[6]Gm/lb: Zn, 34.00 ($ZnSO_4$, 84.g/lb); Mn, 34.00 ($MnSO_4$, 94 g/lb); Fe, 4.50($FeSO_4 \cdot 7H_2O$, 22.5 g/lb); Cu, 0.70 ($CuSO_4$, 1.75 g/lb); I, 0.23 (KIO_3 0.38 g/lb); diluted to 1.00 lb with cereal product.

[7]Mg/lb: d-biotin, 18.0; vitamin B_6 535.0 (pyridoxine.HCl, 650 mg); B_{12}, 1.8; vitamin C, 27,000.0 (ascorbic acid); vitamin E, 15,200.0 (water dispersible alpha tocopheryl acetate): folacin, 385.0 (folic acid); Myo-inositol, 4000.0 (not phytate); vitamin K, 180.0 (menadione sodium bisulfite complex, 545 mg); niacin, 5700.0; d-pantothenic acid, 3200.0 (d-calcium pantothenate, 3478 mg or d,l-calcium pantothenate, 6957 mg; riboflavin, 1600.0; thiamine, 715.0 (thiamine mononitrate, 778 mg); dilute to 1.0 lb with cereal product

[8]Spray dried whole blood

[9]Concentrated bone-free hydrolsate of salmon carcasses, groundfish carcass waste and whole Pacific hake

[10]Liquid, 70%

[11]Two or more of the following, with none exceeding 50% of the combination; (1) Salmon or tuna viscera (no heads or gills, with livers); (2) whole herring; (3) bottom fish (whole or fillet scrap); (4) dogfish; (5) whole hake; and (6) whole salmon. Approved enzymes used to aid liquefaction.

[12]Herring, salmon, menhaden, dogfish (not more than 3%), or refined tuna oil; stabilized with .04% BHA-BHT (1:1); free fatty acids not more than 3%; BHA-BHT must be added at the time of reprocessing if reprocessed oil is used. Special condition when using hake as a wet fish: add 0.5% oil for every 10% hake in total ration.

[13]Herring oil; stabilized with 0.04% BHA-BHT (1:1); free fatty acids $\leq$ 3%.

[14]Vacuum dried

Appendix III. Growth response data. 1983- Brood coho salmon; Sandy Hatchery.

Ration:	Salmon		Hake		(MP	
Pond No.:	3	14	4	13	6	15
No. fish ponded (5/31/84)	57981	57981	57981	57981	57981)	57981
Weight of fish/pond (6/1/84) (kg)	123.8	123.8	123.8	323.8	123.8	123.81
Weight of fish/pond (6/1/84) (lb)	273.0	273.0	273.01	273.0	273.0	273.0
Mean fish wt. (6/1/84) (g)	2.34	2.14	2.141	2.14	2.34	2.141
Wan fish wt. (6/1/84) (fish/lb)	212.36	212.36	212.36	212.36	212.36	212.36
Feed consumed (wet wt.) (kg)	1968.1	1994.4	2010.81	2037.5	2491.6	2508.4)
Feed consumed (wet wt.) (lb)	4339	4397	4433	4492	5493	5530
Feed consumed (dry wt.) (kg)	1493.8	1513.5	1518.6	1538.6	1778.9	179..90
Feed consumed (dry wt.) (lb)	3293.2	3336.7	3348.01	3392.1	3921.7	3948.2)
Feed protein consumed (kg)	824.2	835.2	812.0	822.9	915.3	921.51
Feed protein consumed (lb)	1817.1	1841.3	1790.2	1814.2	2017.9	2031.71
No. of fish released (4/30/85)	56272	57334	56801)	57211	56563	573241
No. mortalities (6/1/84-4/30/85)	1709	647	1180	770	1418	657
Weight of fish/pond (4/30/85) (kg)	1655.2	1682.0	1633.21	1655.1	1778.3	1872.71
Weight of fish/pond (4/30/85) (lb)	W9.1	3708.1	36.00.6	3648.8	3920.6	4128.51
Mean fish might (4/30/85) (g)	29.41	29.34	28.75	28.93	31.44	32.67
Mean fish might (4/30/85) (fish/lb)	15.42	15.461	15.781	15.68	14.43	13.88
Length of fish (4/30/85) (m)	140.9	140.81	140.1	139.3	141.7	141.6
No. tagged fish released (4/30/85	266731	257431	25498	258271	25683	26459
Tag code	7-30-48	7-31-06	7-30-47	7-31-07	7-30-45	7-31-05

Appendix IV. Growth response data. 1984-Brood fall chinook; Bonneville Hatchery

Ration:	OMP		Salmon	
Pond No.:	D-8	D-9	D-4	D-5
No. fish ponded (12/28/84)	564113		504766	
Weight of fish (12/28/84) (g)	.61		.64	
Weight of fish (12/28/84) (fish/lb)	737.55		712.08	
Weight of fish/pond (12/28/84) (lb)	764.8		708.9	
No. fish prior to split #1 (1/31/85)	558829		501656	
Weight of fish prior to split #1 (1/31/85) (g)	1.55		1.44	
Weight of fish/pond (1/31/85) (lb)	1912.1		1593.7	
No. of fish after split #1 (1/31/85)	260957	247270	215560	215480
Weight of fish after split #1 (1/31/85) (g)	1.58	1.52	1.43	1.46
Weight of fish/pond after split #1 (1/31/85) (lb)	910.7	829.2	681.0	691.2
No. of fish prior to split #2 (4/6/85)	258867	243990		
Weight of fish prior to split #2 (4/6/85) (g)	4.40	4.40		
Weight of fish/pond prior to split #2 (4/6/85) (lb)	2513.4	2368.9		
No. fish after split #2 (4/6/85)	228001	227888		
Weight of fish after split #2 (4/6/85) (g)	4.40	4.40		
Weight of fish/pond after split #2 (4/6/85) (lb)	2213.7	2212.6		
No. fish prior to split #3 (4/29/85	227776	227235		
Weight of fish prior to split #3 (4/29/85) (g)	6.47	6.57		
Weight of fish/pond prior to split #3 (4/29/85) (lb)	3250.48	3290.85		
No. fish after split #3 (4/30/85)	151214	151527		
Weight of fish after split #3 (4/30/85) (g)	6.47	6.57		
Weight of fish/pond after split #3 (4/30/85) (lb)	2157.9	2194.4		
No. fish at release (5/13/85)	150774	151055	212060	213251
Weight of fish at release (5/13/85) (g)	7.39	7.81	6.19	5.98
Weight of fish at release (5/13/85) (fish/lb)	61.37	58.09	73.23	75.88
Fish length (mm)	87.8	89.3	83.3	82.0
Weight of fish/pond at release (5/13/85) (kg)	1114.4	1179.4	1313.5	1274.8
Weight of fish/pond at release (5/13/85) (lb)	2456.8	2600.2	2895.8	2810.5
No. of recognizable tagged fish released	78962	78367	80242	79750
Tag code	7-33-23	7-33-22	7-33-24	7-33-25
Feed consumption wet wt. (12/28/84-1/31/85) (lb)	1429		989	
Feed consumption wet wt. (1/31-5/13/85) (lb)	3662	3857	2912	2867
Total feed wet wt.(half 12/28-1/31 to each pond) (lb)	4376	4572	3406	3362
Total feed wet wt.(half 12/28-1/31 to each pond) (kg)	1985.1	2073.6	1545.2	1524.8
Feed consumption dry wt. (12/28/84-1/31/85) (lb)	1070.2		753.6	
Feed consumption dry wt. (1/31-5/13/85) (lb)	2690.8	2832.9	2207.2	2174.5
Total feed dry wt.(half 12/28-1/31 to each pond) (lb)	3225.9	3368.0	2584.0	2551.3
Total feed dry wt.(half 12/28-1/31 to each pond) (kg)	1463.3	1527.7	1172.1	1157.3
Protein consumption (12/28/84-1/31/85) (lb)	583.7		422.4	
Protein consumption (1/31-5/13/85) (lb)	1381.5	1455.9	1217.5	1201.0
Total protein (half 12/28-1/31 to each pond) (lb)	1673.3	1747.7	1428.8	1412.3
Total protein (half 12/28-1/31 to each pond) (kg)	759.0	792.7	648.1	640.6
Mortality (12/28/84-1/31/85)	5284		3110	
Mortality (1/31-4/6/85)	2090	3280		
Mortality (4/6-4/29/85)	225	653		
Mortality (4/30-5/13/85) (1/31-5/13/85)	440	472	3500	2229